IOT Based Preventive Maintenance for Electrical Machine and Industrial Automation

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Abstract - *IoT-based preventive maintenance has emerged as an advanced solution for improving the reliability and efficiency of electrical machines and industrial automation systems. In this project, smart sensors such as temperature, vibration, and humidity are integrated with microcontrollers and Wi-Fi modules to continuously monitor machine health. The collected data is transmitted to a cloud platform where it is analyzed to identify early signs of wear, overheating, or abnormal operating conditions. Whenever critical thresholds are reached, alerts are generated through buzzers and display units, enabling timely corrective action. This proactive approach minimizes unexpected breakdowns, reduces maintenance costs, extends equipment life, and enhances overall productivity. By combining IoT technology with predictive maintenance strategies, the project demonstrates a practical step toward smarter and more sustainable industrial automation.*

Key Words: Temperature, Vibration, Current, Humidity, Sensors, Wi-Fi Module, Cloud Computing, Industrial Automation.

1. INTRODUCTION

In today's industrial world, keeping electrical machines and automation systems running without stops is key to making production work better, keeping things safe, and saving money. Old ways of fixing machines, like waiting for problems to happen or fixing them only when they break, often cause unexpected stops, higher costs, and shorter lifespans for equipment. Now, with the Internet of Things (IoT), industries can make changes and can maintain their equipment from just fixing things after they break to predicting and stopping problems before they happen.

IoT-based maintenance uses smart sensors, cloud computing, and real-time data to keep a close eye on the condition of electrical machines. These sensors track things like temperature, vibration, humidity, and how much energy the machines use. This helps find early signs of wear, problems, or unusual behaviour. By linking these data insights with automation systems, maintenance can be planned ahead of time, which lowers the chance of unexpected breakdowns and makes use of resources more efficiently.

Our project is about creating and setting up an IoT system that can be very helpful with preventive maintenance for electrical machines in industries. This project will help to improve the reliability and efficiency of the machines and will also help to reach the goals of Industry 4.0, where smart decisions and data-based maintenance form the basis of modern manufacturing.

2. LITERATURE REVIEW

2.1 IOT-Enabled Predictive Maintenance in Industry 4.0:

The Industry 4.0 paradigm has significantly transformed manufacturing and production systems by integrating cyber-physical systems (CPS), Internet of Things (IoT), cloud computing, big data analytics, and artificial intelligence. One of the most impactful applications emerging from this transformation is predictive maintenance (PDM), which aims to anticipate equipment failures before they occur and optimize maintenance scheduling, cost, and asset availability. Traditional maintenance strategies such as reactive maintenance (repair after failure) and preventive maintenance (time-based maintenance) are increasingly inadequate in modern industrial environments due to their inefficiency, high downtime, and unnecessary maintenance actions. In contrast, PDM relies on real-time condition monitoring and data-driven decision-making, making it highly aligned with Industry 4.0 objectives.

2.2. IOT-Based Condition Monitoring and Fault Detection of AC Induction Motors :

AC induction motors are widely used in industrial applications due to their robustness, simplicity, and cost-effectiveness. However, unexpected motor failures can lead to costly downtime, safety risks, and reduced production efficiency. To address these challenges, researchers have increasingly focused on condition monitoring and fault detection systems that leverage IoT technologies for real-time monitoring and predictive maintenance. Sensor-Based Condition Monitoring of Induction Motors. Several studies highlight the importance of using multi-sensor approaches to capture the complex behaviour of induction motors. Commonly monitored parameters include temperature, vibration, current, voltage, and rotational speed, as these variables provide early indicators of faults such as bearing failure, stator winding faults, rotor bar defects, misalignment, and overload conditions. Literature shows that temperature sensors are effective in identifying overheating caused by insulation degradation or excessive loading. Vibration sensors are widely used to detect mechanical faults such as bearing wear, shaft imbalance, and misalignment. Current and voltage sensors enable electrical fault diagnosis, including phase imbalance, short circuits, and power quality disturbances. Speed (RPM) sensors provide insights into slip variations and mechanical degradation. The integration of these sensors enhances diagnostic accuracy and fault coverage compared to single-parameter monitoring systems.

2.3. IOT-enabled Remote Monitoring and Predictive Maintenance for Refrigerator and Cold Storage Systems (RCSS) :

Refrigerator and Cold Storage Systems (RCSS), commonly referred to as the cold chain, play a crucial role in preserving temperature-sensitive goods across food, pharmaceutical, and chemical industries. These systems maintain strict temperature conditions throughout storage and transportation to prevent spoilage, quality degradation, and economic loss. The operational reliability of RCSS is therefore critical, as unexpected failures or performance degradation in components such as compressors, evaporators, and control units can lead to significant financial and product losses. Traditional maintenance strategies for RCSS—such as reactive maintenance (repair after failure) and time-based preventive maintenance—are no longer sufficient due to increased complexity and stricter uptime requirements. These conventional methods either fail to anticipate failures or result in premature servicing, both of which negatively impact system availability and maintenance costs. To address these challenges, the emergence of Industry 4.0 has introduced advanced technologies like the Internet of Things (IoT), Big Data analytics, and Machine Learning (ML) into the realm of equipment maintenance.

2.4. Industry 4.0 and IIoT-Based Predictive Maintenance:

The advent of Industry 4.0 has transformed conventional manufacturing systems by integrating advanced digital technologies such as Big Data Analytics, Machine Learning (ML), and Industrial Internet of Things (IIOT) into traditional production environments. This convergence enables the evolution of manufacturing systems into smart manufacturing, where physical assets are interconnected, data-driven, and capable of intelligent decision-making. Smart manufacturing emphasizes automation, adaptability, transparency, and predictive capabilities to enhance productivity and operational efficiency. In smart manufacturing environments, IIoT sensors are deployed on industrial assets such as motors, pumps, compressors, and machining tools to continuously collect real-time operational data. These sensors monitor critical parameters including vibration, temperature, current, pressure, speed, and energy consumption. The continuous flow of sensor data enables machines and systems to autonomously exchange information, thereby forming cyber-physical systems (CPS) that bridge the physical and digital worlds. Such connectivity supports informed and timely business decisions by offering deep insights into asset health and production performance.

2.5. IOT-Driven Predictive Maintenance for System Longevity and Sustainable Operations :

The rapid advancement of the Internet of Things (IoT) has significantly transformed maintenance strategies across mechanical and electrical systems. Traditional maintenance approaches—namely corrective and time-based preventive maintenance—have proven insufficient in addressing the increasing complexity, operational demands, and sustainability requirements of modern industrial systems. In response, IoT-driven Predictive Maintenance (PdM) has emerged as a data-centric paradigm that leverages continuous monitoring, advanced analytics, and intelligent decision-making to enhance system reliability, longevity, and sustainability. The literature consistently reports that IoT-driven predictive maintenance significantly improves system longevity and operational efficiency. By detecting incipient faults at an early stage, PDM systems prevent minor issues from escalating into catastrophic failures. This proactive approach minimizes mechanical stress, optimizes operational parameters, and reduces wear and tear on critical components.

2.6. Industry 4.0–Based Predictive Maintenance Using IoT, SIM, Deep Learning, and Fuzzy Logic:

The emergence of Industry 4.0 has significantly transformed maintenance management strategies in modern manufacturing systems. Traditional maintenance approaches, including reactive maintenance and preventive maintenance (PM), are increasingly inadequate in addressing the complexity, automation, and high availability requirements of contemporary production lines. Reactive maintenance often leads to unexpected downtime and high repair costs, while time-based preventive maintenance may result in unnecessary interventions and inefficient resource utilization. Consequently, Predictive Maintenance (PdM) has gained considerable attention as a data-driven approach that leverages Industry 4.0 technologies to anticipate failures and optimize maintenance planning. Recent literature highlights the integration of advanced automation technologies, Artificial Intelligence (AI), and Industrial Internet of Things (IIoT) as key enablers of predictive maintenance systems. IoT-based architectures facilitate continuous monitoring of production equipment by deploying sensors that capture critical operating parameters such as vibration, temperature, pressure, acoustic signals, and electrical characteristics. These data streams provide the foundation for intelligent analytics that can detect degradation patterns and predict failures before they disrupt production.

2.7. Intelligent Sensors and Predictive Maintenance in Smart Factories:

The rapid advancement of Industry 4.0 technologies has significantly reshaped modern manufacturing environments, giving rise to smart factories characterized by automation, digitalization, and interconnected systems. One of the most prominent transformations within this paradigm is the increasing integration of automated predictive maintenance (PDM) with production Robot. As manufacturing systems become more complex and autonomous, ensuring equipment reliability and minimizing unplanned downtime have become critical objectives. Predictive maintenance plays a pivotal role in achieving these objectives by enabling data-driven maintenance strategies supported by intelligent sensing technologies.

2.8. IoT-Based Predictive Maintenance for Healthcare Equipment in Hospitals:

The efficiency and success of service-oriented industries are closely linked to their ability to deliver high-quality services while maintaining high levels of productivity. In the healthcare sector, particularly in hospitals, the reliability and availability of medical and mechanical equipment directly influence patient satisfaction, service continuity, and operational effectiveness. Equipment downtime in hospitals can result in long waiting times, delayed diagnoses, and compromised patient care. Therefore, effective maintenance strategies are essential for ensuring uninterrupted healthcare services. In many developing regions, including Rwanda, hospital maintenance practices are predominantly reactive, where equipment is repaired only after a failure occurs. The literature highlights that such repair-after-failure approaches often lead to unplanned maintenance activities, increased costs, inefficient use of resources, and partial or complete interruption of hospital operations. Reactive maintenance is particularly problematic in healthcare environments, where equipment failures can directly affect patient safety and service delivery.

2.9. IoT-Based Smart Office Automation and Predictive Maintenance:

The Internet of Things (IoT) has emerged as a transformative platform that facilitates seamless interaction between physical objects and humans by enabling real-time data collection, communication, and intelligent control. IoT applications span diverse domains, including smart homes, smart cities, healthcare, industrial automation, and smart offices. Among these, smart office automation systems have gained significant attention due to their potential to enhance operational efficiency, user convenience, energy management, and workplace safety. Traditional office automation systems primarily rely on wired or short-range wireless communication technologies and are often characterized by limited scalability, high deployment costs, and inflexible user interfaces. The literature identifies several limitations in existing systems, including unfriendly user interfaces, lack of integration with modern IoT platforms, restricted wireless transmission ranges, and limited support for real-time data analytics. These shortcomings hinder user adoption and reduce the effectiveness of automation solutions in dynamic office environments.

2.10. Machine Learning–Based Predictive Maintenance for Building Installations:

The operation and maintenance of buildings have undergone significant transformation in recent years due to advancements in information and communication technologies (ICT). Modern buildings increasingly rely on automated systems and smart devices to manage complex installations such as heating, ventilation, and air conditioning (HVAC), lighting, and energy management systems. Despite these advancements, building maintenance practices often remain inefficient, leading to excessive energy consumption, increased operational costs, and suboptimal system performance. As a result, there is growing interest in adopting predictive maintenance (PDM) strategies to improve building operation and sustainability. Recent literature proposes structured predictive maintenance frameworks to guide the implementation of PDM in building systems. Such frameworks commonly define a sequence of steps encompassing data acquisition, data processing, model development, fault detection, and continuous improvement. A five-step framework—consisting of data collection, data processing, model development, fault notification, and model improvement—has been identified as a systematic approach for deploying PDM in building installations.

2.11. IoT-Based Predictive Maintenance for Energy-Efficient and Sustainable Industrial Facilities:

The increasing global emphasis on energy efficiency, sustainability, and renewable energy integration has accelerated the adoption of advanced digital technologies in industrial facilities. Among these technologies, the Internet of Things (IoT) has emerged as a key enabler for transforming traditional maintenance practices into intelligent, data-driven systems. In particular, IoT-based predictive maintenance (PdM) has gained considerable attention for its potential to improve equipment reliability, reduce energy consumption, and support the integration of renewable energy sources within industrial operations. Recent literature highlights that industrial facilities are characterized by energy-intensive processes and complex machinery, making maintenance optimization critical for reducing operational costs and environmental impact. IoT technologies facilitate continuous monitoring of industrial equipment through distributed sensors that measure parameters such as vibration, temperature, pressure, current, and power consumption. These sensors generate real-time data streams that enable predictive algorithms to assess equipment health and forecast potential failures.

2.12. IoT- and Machine Learning–Based Predictive Maintenance for Medical Imaging Equipment:

Predictive Maintenance (PDM) has gained increasing importance in healthcare environments, where the reliability and continuous availability of medical equipment are critical for patient diagnosis and treatment. Unlike conventional maintenance strategies, PDM focuses on identifying the real-time condition of equipment and forecasting potential failures before they occur, thereby minimizing downtime and improving operational efficiency. This is particularly crucial for high-value and mission-critical medical devices such as Computed Tomography (CT) scan machines, where unexpected breakdowns can lead to delayed diagnoses, increased operational costs, and compromised patient care. Traditional maintenance practices for medical equipment are often based on periodic inspections or corrective maintenance after failure. The literature highlights that such approaches are inefficient for complex imaging systems, as failures can occur unpredictably and may not align with scheduled maintenance intervals. As a result, healthcare institutions increasingly explore data-driven predictive maintenance approaches to improve equipment reliability and utilization. Recent studies emphasize that PDM for medical equipment relies heavily on continuous monitoring of environmental and operational parameters. Key indicators such as temperature, humidity, electrical current, vibration, and radiation exposure have been identified as critical factors influencing the performance and lifespan of imaging systems. Monitoring these parameters allows early detection of abnormal operating conditions that may lead to system degradation or failure.

2.13. Predictive Maintenance Using Machine Learning in Industry 4.0 Manufacturing:

Predictive maintenance (PDM) has emerged as a critical strategy for improving asset management and operational efficiency in modern manufacturing industries. As industrial environments increasingly rely on advanced, complex, and cost-intensive machinery, ensuring equipment reliability and preventing performance degradation have become essential for maintaining productivity and competitiveness. Unlike traditional reactive or time-based preventive maintenance approaches, predictive maintenance enables early detection of potential faults, thereby protecting machinery before significant degradation occurs. Recent developments in the manufacturing sector emphasize the adoption of data-driven maintenance strategies. With the rapid growth of digital transformation initiatives and the transition toward Industry 4.0 (I4.0), manufacturing systems are becoming highly interconnected and intelligent. The integration of advanced data acquisition technologies, process management systems, and communication networks makes it possible to collect large volumes of operational and process-related data from various industrial assets. This data forms the foundation for automated fault detection, diagnostics, and prognostics. The literature highlights that PdM plays an inevitable role in ensuring asset health, reduced downtime, and extended Remaining Useful Life (RUL) of industrial equipment. Predictive maintenance is increasingly recognized as a cornerstone of smart manufacturing, enabling manufacturers to improve equipment utilization rates while reducing maintenance costs and production losses.

2.14. IIoT-Based Monitoring and Predictive Maintenance for Electric Motors:

The adoption of Industrial Internet of Things (IIoT) technologies has transformed the monitoring and maintenance of industrial equipment, particularly electric motors, which are critical assets in manufacturing and processing industries. Electric motors account for a significant portion of industrial energy consumption and production operations; therefore, ensuring their reliable operation is vital to minimizing downtime, reducing operational costs, and improving overall plant efficiency. IIoT systems enable continuous, real-time monitoring of industrial assets by integrating multisensory microcontrollers, gateways, and cloud analytics platforms. Sensors embedded in or around motors capture parameters such as vibration, temperature, current, and rotational speed, which serve as indicators of equipment health. The literature emphasizes that vibration and temperature monitoring are particularly effective for early detection of anomalies such as bearing wear, rotor imbalance, misalignment, or overheating. Recent studies highlight that low-cost IIoT solutions using open-source hardware and software provide a feasible and scalable approach for industrial applications. Microcontrollers such 3.as Arduino or ESP32, coupled with single-board computers like Raspberry Pi as gateways, allow real-time data acquisition and preliminary processing before sending data to cloud platforms. This enables cost-effective monitoring without requiring expensive industrial-grade equipment.

2.15. Automated Machine Learning (Auto ML) for IIoT-Based Predictive Maintenance:

The rapid growth of Industrial Internet of Things (IIoT) systems in modern manufacturing and energy sectors has led to the generation of increasingly complex datasets. These datasets, derived from multiple sensors and connected devices, provide valuable insights into equipment health and operational conditions. However, the high dimensionality, volume, and heterogeneity of IIoT data present substantial challenges for traditional machine learning (ML) techniques, which often require extensive manual feature selection, hyperparameter tuning, and computational resources to develop accurate predictive maintenance (PDM) models. Traditional ML approaches, while effective in smaller or well-curated datasets, often struggle to scale with the complexity of IIoT environments. Predictive maintenance applications, such as fault detection and remaining useful life (RUL) prediction for rotating machinery, require models that can process high-dimensional sensor data in real-time. Manual ML pipelines are time-consuming and prone to suboptimal configurations, which can lead to reduced predictive performance, increased development costs, and slower deployment in industrial settings.

3. COMPONENTS USED

A. Wi-Fi Module

A Wi-Fi Module is an electronic component that enables wireless communication between the devices and the internet using standard Wi-Fi protocols. It acts as a bridge that allows microcontrollers, sensors, or embedded systems to transmit and receive data without wired connections. Commonly used modules, such as ESP8266 and ESP32, integrate a microcontroller with built-in TCP/IP stack, making them highly efficient for IoT applications.

Fig 1: Wi-Fi Module

In preventive maintenance and industrial automation, Wi-Fi modules provide seamless connectivity for real-time data transfer from machines to cloud servers or monitoring dashboards. Wi-Fi Module supports features like low-power consumption, high data rate, and secure encryption, which are crucial for reliable and scalable in IoT systems. By using a Wi-Fi module, industries can keep an eye on machines from far away, use the data to spot issues before they occur, and make smarter choices, which makes the machines perform better and stay working for longer.

B. Cloud System

A cloud system is a digital platform that gives people access to computing tools like storing data, using processing power, connecting networks, and running applications over the internet, instead of relying on physical computers. It allows users to access, share, and work with information whenever they want and from any where they want, using devices that are connected to the internet. In a preventive maintenance system that uses the Internet of Things (IoT), the cloud system plays a key role because it collects data from sensors, stores it securely, and uses smart tools to process the information. This helps in checking things in real time, making quick decisions, and predicting issues before they happen, without needing a lot of physical equipment at the user's location. Cloud systems can expand as needed, save costs, and work well with automated industrial systems.

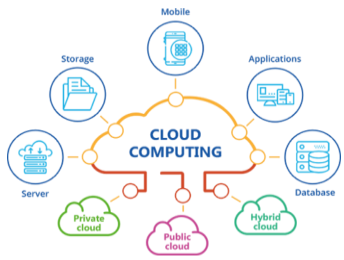

Fig 2: Cloud System

C. Temperature Sensor

A Temperature Sensor is an electronic tool that measures how hot or cold something is and changes that information into electrical signals, which help in keeping track of and managing temperature. In this preventive maintenance systems, these temperature sensor plays a very important role in tracking the operating temperature of electrical machines. Even a small increase beyond the usual level can show problems in machines like too much load, not enough oil, damaged insulation, or a broken cooling system etc.

Modern temperature sensors come in different types, such as thermocouples, resistance temperature detectors (RTDs),

Fig 3: Temperature Sensor

and semiconductor-based sensors. When these sensors are connected to the IoT platforms, they provide continuous and real-time data that can be stored and analyzed in the cloud system. This enables early fault detection, reduces downtime, and helps extend machine lifespan by preventing overheating-related failures.

D. Vibration Sensor

A Vibration Sensor is a smart device used to detect and measure oscillations, movements, or disturbances in machines and structures. It works by turning mechanical vibrations into electrical signals, which are then used to check the condition of the equipment. In industrial applications, vibration sensors are crucial for monitoring rotating machines such as motors, pumps, fans, and gearboxes, as abnormal vibration often indicates imbalance, misalignment, or wear in components.

Fig 4: Cloud System

When integrated with IoT systems, vibration sensors provide real-time data that helps predict potential faults before they escalate into major breakdowns. This allows industries to implement preventive maintenance strategies, reduce downtime, and extend the life of electrical machines. Due to their accuracy and ability to continuously monitor machine health, vibration sensors are considered a key element in industrial automation and predictive maintenance frameworks.

E. Humidity Sensor

A Humidity Sensor is an electronic device that measures the amount of water vapor present in the surrounding air. It plays a vital role in applications where environmental conditions directly affect the performance and safety of equipment. In IoT-based preventive maintenance, humidity sensors are used to monitor the moisture levels around electrical machines, since excessive humidity can lead to insulation damage, corrosion of components, and unexpected failures.

Fig 5: Humidity Sensor

These sensors typically work by detecting changes in electrical properties such as capacitance or resistance when exposed to moisture. The data that is gathered is sent to a microcontroller or an IoT platform, where it is checked and studied as it happens. By keeping an eye on humidity levels, industries can stop problems such as short circuits overheating, and lower machine performance, which helps make the equipment last longer.

F. Buzzer

A buzzer is an electronic gadget that produces a sound when it receives power. It is often used in various projects, in industrial environments, and internet-connected devices to let people know about problems. Buzzers can create a continuous sound or a sound that turns on and off, based on how they are programmed.

In maintenance work, buzzers are very important because they give a loud sound right away when something goes wrong, like when temperature, movement, or dampness goes beyond safe levels. This helps workers know quickly when something is not right and take steps to fix it before the problem gets worse.

Fig 6: Buzzer

Buzzers are light, cheap, and easy to connect to small computers, which makes them great for monitoring systems that use the internet. Their ability to grab attention quickly makes them dependable in helping keep industrial systems safe, efficient, and responsive.

G. Step Down Transformer

A step-down transformer is a device that reduces high voltage to a safer and usable level while keeping the same frequency. It works through electromagnetic induction and includes two coils. The primary coil is connected to the high-voltage source, and the secondary coil provides the lower voltage. The amount of voltage reduction depends on the number of turns in each coil. If the main coil has more loops than the secondary coil, the voltage coming out is lower. Step-down transformers are important in both big industrial settings and everyday home use.

Fig 7: Step Down Transformer

4. SYSTEM MODELING

A. Block Diagram

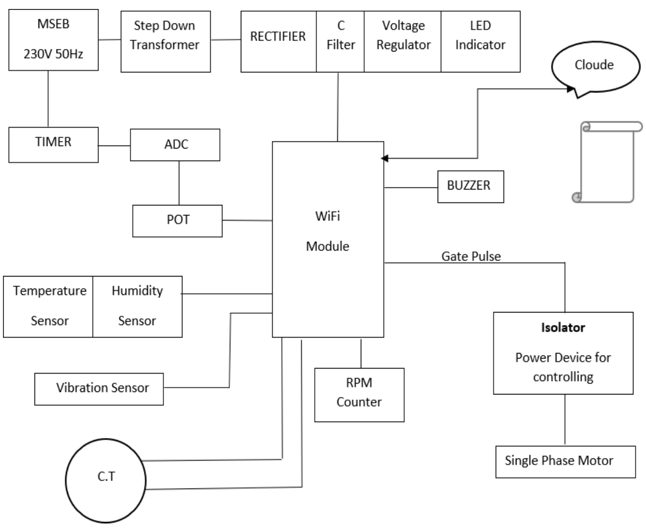

Fig 8: Block Diagram of IOT Based Preventive Maintenance for Electrical Machine and Industrial Automation

B. Circuit Diagram

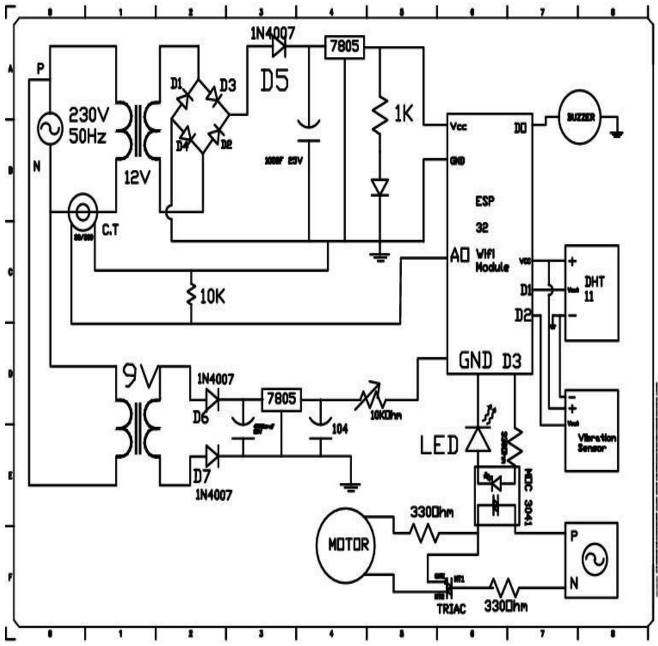

Fig 9: Circuit Diagram

Table 1: Proposed Data

Sensor Type	Measurement Parameter	Application	Data Frequency	Typical Accuracy
Vibration Sensor	Vibration frequency and amplitude	Motor, pumps, fans	1Hz - 1kHz	±2%
Temperature Sensor	Temperature	Motors, transformers , bearings	1Hz - 1kHz	±0.5°C
Current Sensor	Current consumption	Motors, generators	1Hz - 100Hz	±1%
Pressure Sensor	Pressure	Hydraulic systems, compressors	1Hz - 1kHz	±0.3%
Humidiy Sensor	Humidity	Electrical panels, enclosures	1Hz - 1kHz	±2%

A. PROGRAMMING LANGUAGE USED

I have used Java Programming Language for this project. Java programming plays a crucial role in building intelligent, cross-platform, and secure IoT applications that monitor and manage electrical machines in an industrial automation environment. It acts as the software backbone that connects IoT sensors, controllers, cloud platforms, and analytics systems to enable preventive maintenance.

B. COMMUNICATION PROTOCOLS

Reliable and efficient data transmission is ensured through the use of standard communication protocols used in industry.

- **MQTT (Message Queuing Telemetry Transport):** Small and ideal for use in platforms with limited bandwidth.
- **CoAP (Constrained Application Protocol)**: It is a protocol that works well with small devices or any device that doesn't have a lot of memory.
- **Ethernet/IP:** This is widely described in the field of industrial automation where data is transferred at high rate.

These protocols enable efficient interaction to occur between sensors, edge devices and cloud platforms.

C. WORKING

1. Sensing Layer (Data Collection)

Different sensors are installed on the electrical machines:

- **Temperature Sensor (LM35/DS18B20) →** detects overheating.
- **Vibration Sensor (Piezo/Vibration Sensor Module)** → detects abnormal vibrations due to misalignment or bearing faults.
- **Current Sensor (ACS712) →** monitors load current, detects overcurrent or under current conditions.
- **Humidity Sensor (DHT11/DHT22)** → checks surrounding moisture levels that may damage machines.

These sensors continuously collect real-time health data from the machine.

2. Processing Layer (Microcontroller/Edge Device)

- A microcontroller (Arduino/ESP32/Node MCU/Raspberry Pi) collects sensor data.
- The microcontroller processes the readings and compares them with predefined threshold values (safe operating ranges).
- **If a parameter exceeds its limit:**
  - The system detects it as a fault prediction or preventive alert condition.
  - **Example:** If motor temperature > 70°C → overheating warning.

3. Communication Layer (IoT Connectivity)

- The processed data is sent to a cloud server or IoT platform via Wi-Fi, GSM, or MQTT protocol.
- Popular platforms: Blynk, Thing Speak, Firebase, or custom cloud dashboards.
- This enables remote monitoring of machine health in real time.

4. Application Layer (Monitoring & Alerts)

- Data is displayed on a mobile app, web dashboard, or PC software.
- Users/engineers can visualize machine health with graphs, reports, and logs.
- **If an abnormal condition is detected:**
  - Instant alerts are sent via SMS, Email, or App notifications.
  - **Example:** "Machine Overheating! Please check motor bearings."

5. Preventive Maintenance Action

- Instead of waiting for a breakdown, the operator can schedule maintenance in advance.
- **Preventive actions include:**
  - Lubricating machine bearings when vibration is abnormal.
  - Cooling or shutting down machines in case of overheating.
  - Adjusting load in case of overcurrent detection.

6. Automation & Control

- The system can be integrated with relays/actuators to automatically shut down or control machines if critical conditions occur.
  - **Example:** If current > 10A, relay disconnects the power supply to prevent motor burnout.
- This ensures safety and reliability in industrial automation.

7. Data Analytics & Prediction

- Stored data in the cloud can be used for AI/ML predictive analytics:
  - Predict when a machine is likely to fail.
  - Identify long-term performance trends.
  - Optimize maintenance schedules.

D. EXAMPLE WORKFLOW

1. **Motor is running** → sensors monitor temperature, vibration, and current.
2. **Vibration exceeds threshold** → microcontroller detects anomaly.
3. **Data sent to IoT cloud** → dashboard shows vibration alert. **Notification sent to operator** → "Bearing fault suspected, schedule maintenance."
4. **Operator checks machine early** → prevents costly breakdown.

E. PCB, ENCLOSURE & SAFETY

- Keep mains wiring separated in the enclosure.
- Use screw terminals and strain relief for cables.
- Add surge protection for sensors connected to long cables.
- Consider a small DIN-rail PCB with terminal blocks, opto-isolation, and transient suppression.

F. TESTING & VALIDATION

1. **Unit tests:** Verify each sensor individually (heat the motor, tap to simulate vibration, apply variable load).
2. **Integration tests:** Simulate combined faults and confirm alerts and relay actions.
3. **Fail-safe checks:** Ensure network loss does not inadvertently energize unsafe states — use local watchdogs and default safe outputs.
4. **Record logs** and verify timestamps (sync time via NTP).

G. SAFETY & ISOLATION

- Keep mains wiring separate from low-voltage electronics
- Use opto-isolators or separate power supplies if monitoring high-voltage circuits
- Use proper fusing, earth grounding, and follow local electrical codes

5. RESULT

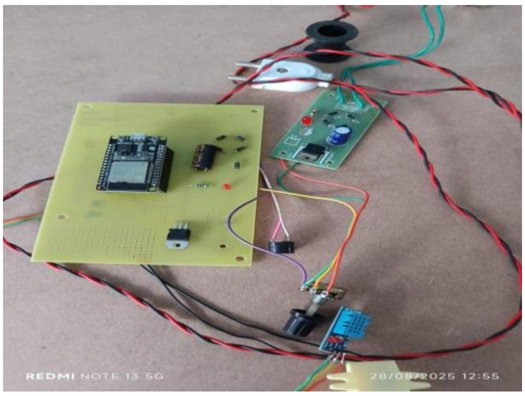

Fig 10: Actual Model

6. SCOPE AND LIMITATIONS

This paper explores the application of IoT for predictive maintenance of industrial electrical machines with an emphasis on real-time monitoring and analysis and does not include non- industrial and manual-based uses of IoT for Predictive maintenance.

7. CONCLUSIONS

The integration of IoT technology with preventive maintenance in electrical machines and industrial automation presents a powerful solution to overcome the challenges of unplanned downtime, equipment failures, and high maintenance costs. By using sensors, microcontrollers, and cloud-based analytics and also this system ensures continuous monitoring of critical machine different parameters such as temperature, vibration, humidity, etc.

By being proactive, we can spot problems early, plan maintenance better, and make sure things run more reliably. Also, using real-time alerts and smart data helps people make better decisions, keeps workers safer, and uses resources more efficiently.

The project shows how IoT can change traditional maintenance methods into smart, predictive, and very efficient systems, which fits with the goals of Industry 4.0. Ultimately, such an implementation not only extends the lifespan of machines but also contributes to improved productivity, cost savings, and sustainable industrial growth.

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